Andreas Wielenberg (GRS) – Siegfried Babst (GRS) – Gerhard Gänssmantel (GRS)

Lessons Learned on Probabilistic Methodology for Precursor Analysis

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Overview

- Introduction
- Emerging Methodological Issues from Precursor Assessments
- Examples from GRS Experience
- Conclusions

Introduction

- Precursor studies utilize PSA models to evaluate the risk significance of events from operating experience
- Precursor event if e.g. 10^{-6} CCDP exceeded
- GRS performs precursor assessments on behalf of German federal regulator BMUB since 1985
  - Complement deterministic operating experience (OPEX) assessment
  - Identify events with reduced margins, exposed weaknesses
  - Identify risk significant events for in-depth analysis
- GRS involved in international precursor studies activities

➢ Our insights on probabilistic methods and assessment related to precursor studies

Emerging Methodological Issues
Completeness of PSA models

- Precursor assessment of OPEX can require model extension
- Gaps in PSA models and potential improvements of methods
- Observations
  - Events motivate the inclusion of new CCF groups/failure modes
  - Identify additional operator actions for control of event sequences to be included in PSA models
  - PSA models often neglect seasonal variations/conditions
  - Simplifying/Deterministic assumptions can mask existing vulnerabilities
  - Re-examine IE grouping & accident sequence modelling in light of new/unexpected plant behaviour from OPEX

Emerging Methodological Issues
Precursor analysis issues - 1

- Events spanning an extended time period
  - Precursor analysis usually aggregates risk figures for the full period
  - PSA results usually with reference to 1 year / operating year
  - Plant configuration changes hard to consider for long duration
  - ➢ Aggregation might be misleading, limit to e.g. 1 year impact, if sensible
- Overlapping events and changes in plant configuration
  - Explicitly time-dependent assessment necessary
  - ➢ Use time-dependent modelling and risk monitor models as available

Emerging Methodological Issues
Precursor analysis issues - 2

- Actual plant configuration in precursor models
  - Common PSA models often include summary unavailabilities for planned maintenance in plant operating states (POS)
  - Need for a “baseline” PSA models with optional maintenance & POS unavailabilities
  - ➢ Risk monitor model constitutes important enhancement
- Treatment of potential CCF
  - CCF event quantification assumes test/detection intervals
  - Precursor analysis period might be significantly smaller
  - ➢ Reconsider CCF quantification, but
  - ➢ Consider potential CCF impact (see example below), too

Emerging Methodological Issues
Precursor analysis issues - 3

- Operator actions and HRA issues
  - OPEX shows that operator actions not considered (relevant) in PSA model may lead to successful control of event
  - Additional operator actions may have large impact on sensitivity cases
  - ➢ Consider both effects in precursor assessments
- Impact on accidental release scenarios
  - German classification insensitive to events from OPEX with degradation of containment function/containment bypass
  - ➢ German classification should be extended in that direction
  - ➢ Note small LRF/LERF values of below 10^{-6} per year

Emerging Methodological Issues
Precursor analysis issues - 4

- Precursor classification
  - German classification (CCDP > 10^{-6}) developed in 1990s
  - Based on then results for internal events at full power PSA
  - Newer models arrive at CDF ~ 10^{-6} and LRF < 10^{-6}
  - ➢ Re-examine (German) precursor classification

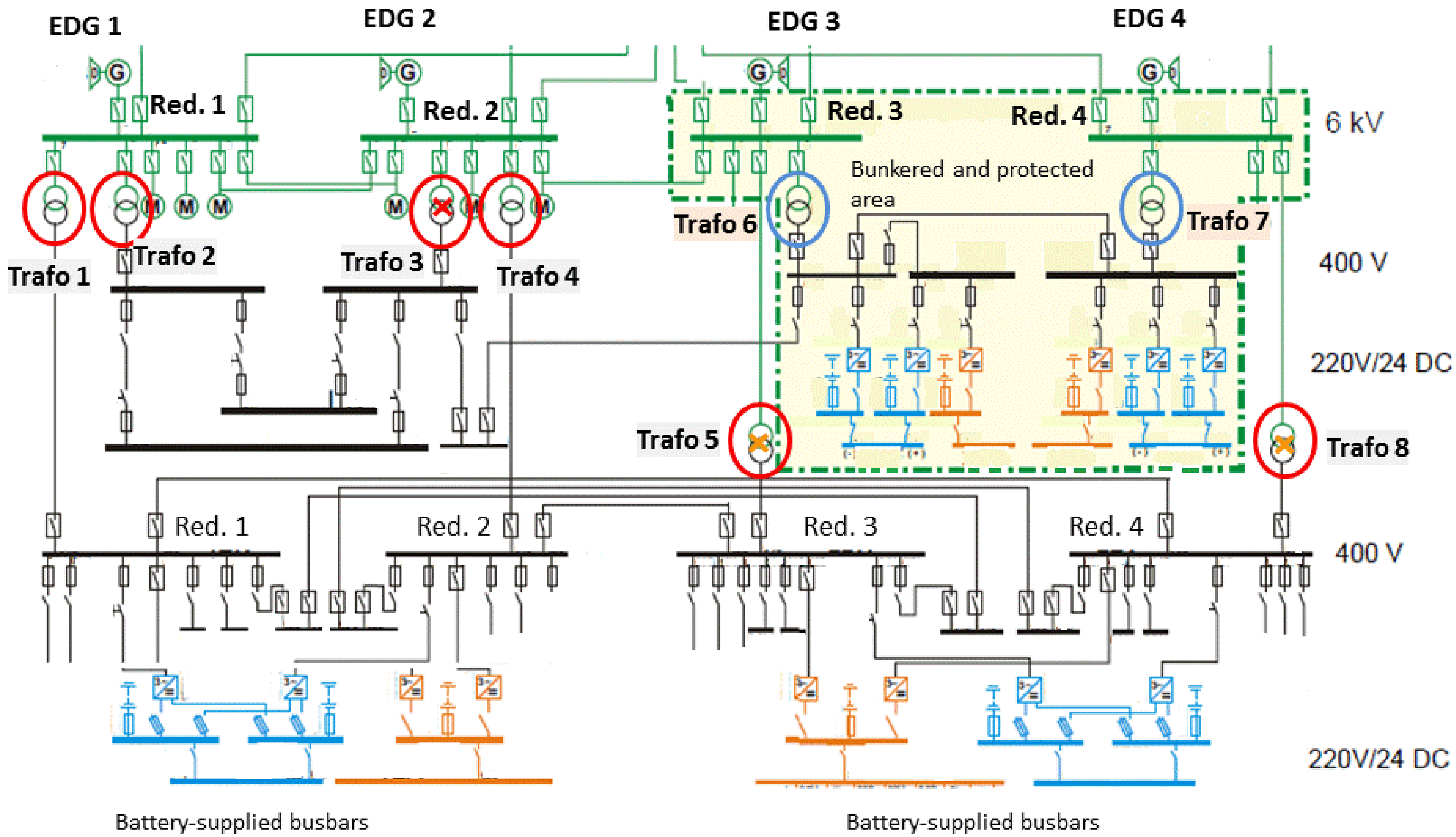
Emerging Methodological Issues
Probabilistic Methods

- Assessment of passive barriers and elements
  - Often assume to be effective in PSA models
  - OPEX shows examples with degradations and failures
  - Comprehensive assessment methods difficult to develop
  - ➢ Perform scoping analyses and sensitivity studies
- Propagation of electrical disturbances
  - Electrical transient propagation (incl. to I&C) hard to model
  - ➢ Research on electrical transient behaviour and PSA modelling needed
- OPEX confirms known limitations of current HRA methods

Potential Loss of UHS and FW due to CCF in medium voltage transformers in the electric power supply

- Event description
  - 6/0.4 kV transformer no. 3 tripped in one train of EPS of auxiliary power supply
  - 400 V busbar and start-up of one EDG unavailable (stop valve in service water system remains closed)
  - Protection signal triggered due to low transformer oil level
  - Oil level low due to
    - Low ambient temperatures (4 °C)
    - Low transformer load
    - Level indicator with non-linear gauge (faulty maintenance)
    - Insufficient maintenance processes and practices
  - No. 5 & 8 transformers found with low oil level afterwards

Overview over auxiliary power system with affected transformers



Transformer failures
Precursor Issues

- Precursor analysis assumptions and results
  - 3 out of 6 CCF event postulated with conditional failure probability for no. 5 of 0.5 and no. 8 of 0.4 $\Rightarrow$ 0.2 for the potential CCF
  - Battery supply of DC busbars for 2 h
  - Consider operator restoration of power supply by manual switchover with failure probability of $6.3 \cdot 10^{-2}$
  - Failure to control the event triggers Loss of UHS and FW due to operational control systems and RPS actions
  - Precursor assessment of sensitivity case ~ $2 \cdot 10^{-6}$
- Issues
  - PSA model should be extended with transformer failure scenarios
  - CCF group for transformers should be included in PSA
  - Potential multi-unit effects

Missing Mineral Wool in Fire Barrier Penetration Seals

- Event description
  - Interstices between fire barrier walls in emergency feedwater building not filled with mineral wool
  - Spread of hot gases, smoke can lead to failures in electronic equipment and I&C of up to 2 additional redundant trains
- Precursor assessment issues
  - Assume ignition frequencies from Fire PSA
  - Conservative assessment (sensitivity case) using plant Fire PSA resulted in precursor classification
  - Fire PSA did not consider this potential degradation
  - ➢ At least sensitivity cases should be conducted regarding impacts of passive barrier failures within hazards PSA

Phase failures in the electrical power supply

- Event description
  - Prominent event(s) outside of Germany (e.g. US) where electrical phase failures did not trip automatic countermeasures
  - Persistent non-isolated faults may affect grid connection, power supply, and damage/make unavailable components
  - GRS recommended plant improvements
- Precursor assessment issues
  - No precursor assessment possible using German PSA models due to lack of specific modelling
  - In principle feasible, by extending power supply modelling, but needing significant resources
  - Effective PSA methods and deterministic simulations identified as an area for future research by GRS

Conclusions

- Emerging issues related to PSA & precursor studies have been identified
- Main lessons
  - Precursor assessment and CCF evaluation activities need to regularly exchange information; PSA models need to be updated
  - Precursor classification should consider containment degradations, classification schemes should be re-examined
  - Use explicitly time-dependent calculations for scenarios persisting over a long time period, considering changes in plant configuration and overlapping events
  - Consider potential failures of passive barriers and safety features at least by scoping analysis and sensitivity studies
- Specific lessons illustrated with examples from German practice

Thank you for your attention!